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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

INVENTOR(S)		
Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
Ilan	BEN-DAVID	Rosh Ha'ayin, Israel

☐ *Additional inventors are being named on the ^ separately numbered sheets attached hereto*

TITLE OF THE INVENTION (280 characters max)

METHOD AND SYSTEM OF CONVERTING PIXEL DATA

Direct all correspondence to: **CORRESPONDENCE ADDRESS**

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ENCLOSED APPLICATION PARTS *(check all that apply)*

☒ Specification *Number of Pages* 12 ☐ CD(s), Number

☒ Drawing(s) *Number of Sheets* 4

☐ Application Data Sheet. See 37 CFR 1.76 ☒ Other (specify) postcard

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT *(check one)*

☒ Applicant claims small entity status. See 37 CFR 1.27.

☐ A check or money order is enclosed to cover the filing fees

FILING FEE AMOUNT ($)

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The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☒ No.

☐ Yes, the name of the U.S. Government agency and the Government contract number are:

Respectfully submitted,

SIGNATURE

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Date 09 / Feb / 2004

REGISTRATION NO. *(if appropriate)* 37,912

Docket Number: P-6575-USP

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

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METHOD AND SYSTEM OF CONVERTING PIXEL DATA

Inventor: Ilan Ben David

Field Of The Invention

The invention relates generally to processing of image data and, more specifically, to conversion of data representing color pixels.

Background

A Liquid Crystal Display (LCD) device may include an array of Liquid Crystal (LC) elements, which may be driven, for example, by Thin Film Transistor (TFT) elements. Each full-color pixel of a displayed image may be reproduced by three sub-pixels, each sub-pixel corresponding to a different primary color, e.g., each full pixel may be reproduced by driving a respective set of LC elements in the LC array, wherein each LC element is associated with a color sub-pixel filter element. For example, three-color sub-pixels may be reproduced by red (R), green (G) and blue (B) sub-pixel filter elements. Thus, each sub-pixel may have a corresponding cell in the LC array.

Unfortunately, due to inherent imperfections in exiting production processes, some LCD devices are produced with one or more defective pixels. A defective pixel may include one or more defective sub-pixels. The defective sub-pixels may include either sub-pixels constantly being in an "open", i.e., unattenuated, state and/or sub-pixels constantly being in a "closed", i.e., fully attenuated, state. In a conventional RGB LCD device, a defective sub-pixel of the constantly "open" type may result in an apparent bright spot being displayed even, for example, when the sub-pixel is intended to be in the "closed" state. Conversely, a defective sub-pixel of the constantly "closed" type may result, for example, in an unintended dark spot or, more significantly, in a colored pixel being displayed where a neutrally colored (e.g., white) pixel was intended, e.g., when all sub-pixels are intended to be switched on. Unfortunately, such defects, e.g., in the form of colored spots, may be easily noticed by a viewer, particularly in neutral color regions (grays) of a displayed image.

Brief Description Of The Drawings

The invention will be understood and appreciated more fully from the following detailed description of embodiments of the invention, taken in conjunction with the accompanying drawings of which:

Fig. 1 is a schematic illustration of a more-than-three primary color display system in accordance with exemplary embodiments of the invention;

Fig. 2 is a schematic illustration of a chromaticity diagram representing the color gamut of a 6-primary display in accordance with an exemplary embodiment of the invention;

Fig. 3 is a schematic flow-chart illustration of a method of correcting defective pixels in accordance with exemplary embodiments of the invention; and

Fig. 4 is a schematic illustration of a system for defective pixel correction according to exemplary embodiments of the invention.

It will be appreciated that for simplicity and clarity of illustration, elements shown in the figures have not necessarily been drawn accurately or to scale. For example, the dimensions of some of the elements may be exaggerated relative to other elements for clarity or several physical components included in one element. Further, where considered appropriate, reference numerals may be repeated among the figures to indicate corresponding or analogous elements. It will be appreciated that these figures present examples of embodiments of the present invention and are not intended to limit the scope of the invention.

Detailed Description Of Embodiments Of The Invention

In the following description, various aspects of the present invention will be described. For purposes of explanation, specific configurations and details are set forth in order to provide a thorough understanding of the present invention. However, it will be apparent to one skilled in the art that the present invention may be practiced without the specific details presented herein. Furthermore, some features of the invention relying on principles and implementations known in the art may be omitted or simplified to avoid obscuring the present invention.

Unless specifically stated otherwise, as apparent from the following discussions, it is appreciated that throughout the specification discussions utilizing terms such as "processing," "computing," "calculating," "determining," or the like, refer to the action and/or processes of an electronic circuit or computing system, or similar electronic computing device, that manipulate and/or transform data represented as physical, such as electronic, quantities within the computing system's registers and/or memories into other data similarly represented as physical quantities within the computing system's memories, registers or other such information storage, transmission or display devices. In addition, the term "plurality" may be used throughout the specification to describe two or more components, devices, elements, parameters and the like.

Embodiments of the present invention may be implemented by software, by hardware, or by any combination of software and/or hardware as may be suitable for specific applications or in accordance with specific design requirements. Embodiments of the present invention may include units and sub-units, which may be separate of each other or combined together, in whole or in part, and may be implemented using specific, multi-purpose or general processors, or devices as are known in the art. Some embodiments of the present invention may include buffers, registers, storage units and/or memory units, for temporary or long-term storage of data and/or in order to facilitate the operation of a specific embodiment.

Certain aspects of monitors and display devices, in accordance with some exemplary embodiments of the invention, are described in International Application PCT/IL02/00307, filed April 13, 2003, entitled "COLOR DISPLAY DEVICES AND METHODS WITH ENHANCED ATTRIBUTES" and published 23 October 2003 as

PCT Publication WO03/088203 ("Reference 1"), the disclosure of which is incorporated herein by reference.

Fig. 1 schematically illustrates an n-primary color display system 200, wherein *n* is greater than three, in accordance with some exemplary embodiments of the invention.

Although aspects of the invention are described herein in the context of an exemplary embodiment of a display using four or more primary colors, it will be appreciated by persons skilled in the art that certain aspects of the invention may also be applicable to display devices and/or methods using only three primary colors, for example, RGB display devices and methods.

System 200 may include a light source 212, an array of liquid crystal (LC) elements (cells) 214, for example, an LC array using Thin Film Transistor (TFT) active-matrix technology, as is known in the art. System 200 may further include electronic circuits ("drivers") 220 for driving the LC array cells, e.g., by active-matrix addressing, as is known in the art, and an n-primary-color filter array 216 juxtaposed the LC array. In embodiments of the LCD devices according to embodiments of the invention, each full-color pixel of the displayed image may be reproduced by more than three sub-pixels, each sub-pixel corresponding to a different primary color, e.g., each pixel may be reproduced by driving a corresponding set of four or more sub-pixels. For each of the four or more sub-pixel there may be a corresponding cell in LC array 214, and each LC cell may be associated with a color filter element in color filter array 216 corresponding to one of four or more, respective, primary colors. Back-illumination source 212 may provide the light needed to produce the color images. The transmittance of each of the sub-pixels may be controlled by the voltage applied to a corresponding LC cell of array 214, based on the image data input for the corresponding pixel. An n-primaries controller 218 may receive the input data, e.g., in RGB or YCC format, may optionally scale the data to a desired size and resolution, and may transmit data representing the magnitude of the signals to be delivered by the different drivers based on the input data for each pixel. The intensity of white light provided by back-illumination source 212 may be spatially modulated by elements of the LC array, thereby selectively controlling the illumination of each sub-pixel according to the image data for the sub-pixel. The selectively attenuated light of each sub-pixel passes through the

corresponding color filter of color filter array 216, thereby producing desired color sub-pixel combinations. The human vision system spatially integrates the light filtered through the different color sub-pixels to perceive a color image.

According to exemplary embodiments of the invention, one or more of the sub-pixels of display 200 may be defective, e.g., LC array 214 may include constantly "open" sub-pixel cells and/or constantly "closed" sub-pixel cells, e.g., regardless of the signal provided by the drivers.

According to embodiments of the invention, a display system, e.g., system 200, may be able to substantially reproduce a desired pixel color by a pixel including n sub-pixels, of which some sub-pixels are defective sub-pixels, e.g., using only at least some of the sub-pixels that are not defective, as described below.

Reference is made to Fig. 2, which schematically illustrates a chromaticity diagram representing the color gamut of a 6-primary, e.g., red (R), green (G), blue (B), cyan (C), yellow (Y) and magenta (M), display in accordance with an exemplary embodiment of the invention.

According to exemplary embodiments of the invention, a pixel of a desired color gamut or a color gamut spectrally similar to the desired color gamut may be reproduced by the n-primary display using only some of the n sub-pixels, e.g., wherein these sub-pixels do not include any of one or more defective sub-pixels, as described below.

For the 6 primary colors illustrated in Fig. 2, a selection of a triad of primary colors may define an effective color gamut, e.g., effective color gamut 1502 may be defined by a YMR triad. According to embodiments of the invention, in order to reproduce a pixel of a desired color gamut, a triad of primary colors may be selected such that an effective color gamut defined by the selected triad may substantially reproduce the desired color gamut, as explained in detail in Reference 1. An effective color gamut may be defined by different color triads, e.g., effective color gamut 1504 may be defined by triads RGB and YCM. Selection of the three primary colors from a set of available triads defining a required effective color gamut may include optimization of display attributes, for example, luminance uniformity, smoothness, or any other objective, subjective or relative display attribute.

According to exemplary embodiments of the invention, a pixel of a desired color gamut may be reproduced using only $l<n$ of the n sub-pixels, e.g., wherein the l sub-pixels do not include any of one or more defective sub-pixels, assuming that the effective color gamut defined by the l sub-pixels includes, i.e., is capable of reproducing, the desired color. For example, a pixel having a color gamut included in field 1502 may be reproduced using only the Y, R and M sub-pixels, e.g., without using the G, C and B sub-pixels. Accordingly, a color gamut included in field 1502 may be reproduced even if one or more of the G, C and B sub-pixels is defective.

According to some exemplary embodiments of the invention, if the effective color gamut defined by the l sub-pixels does not include, i.e., is not capable of reproducing, the desired color, then a color which is spectrally similar to the desired color, or as similar as possible to the desired color, may be reproduced using the l sub-pixels. Additionally or alternatively, a desired color of a pixel may be reproduced by adjusting values of one or sub-pixels of more neighboring pixels. As a result of this adjustment, the adjusted neighboring pixels and/or sub-pixels may be spatially integrated by a viewer to substantially reproduce the intended chromaticity of the defective pixel. It will be appreciated by persons skilled in the art that this aspect of the invention may also be applicable to a three-primary color display, e.g., to accommodate situations where even a defective pixel with only one defective sub-pixel may not be correctable solely by adjusting the values of the other two, non-defective, sub-pixels within the defective pixel.

A selection of a larger number of primary colors, e.g., four or five primary colors, may result in a larger effective color gamut. For example, an effective color gamut including fields 1502, 1504 and field 1506 may be obtained if four primary colors, e.g., C, M, R and Y are selected. Accordingly, the larger the number n of primary colors used by the display, the larger the color gamut that may be reproduced using only some of the sub-pixels.

According to exemplary embodiments of the invention, information regarding defective pixels of a display, e.g., including a location of each defective pixel and/or the identity of one or more defective primary color sub-pixels in the defective pixel, may be recorded, for example, during a testing procedure applied to the display. The testing procedure may include any testing procedure suitable for detecting defective sub-pixels

of the display. For example, the testing procedure may include a testing procedure as described by *Noam Cohen* in *"Automated Optical Inspection for the LTPS TFT-LCD Process", http://www.orbotech.com/tech_lib_fpd.asp?sub=aoi_ltps_tft.* The information obtained by such a testing procedure may be subsequently used in order to enable a defective pixel to reproduce a desired color based on input pixel, e.g., three-primary or more-than three-primary, data, as described below.

According to exemplary embodiments of the invention, a set of i defective pixel types may be defined, based on the defective pixel information. For example, in a six-primary GCBMRY display, a first defective pixel type may correspond to a pixel including a defective R sub-pixel, a second defective pixel type may correspond to a pixel including a defective G sub-pixel, a third defective pixel type may correspond to a pixel including a defective C sub-pixel, a fourth defective pixel type may correspond to a pixel including a defective B sub-pixel, a fifth defective pixel type may correspond to a pixel including a defective Y sub-pixel, and a sixth defective pixel type may correspond to a pixel including a defective M sub-pixel. Other defective pixel types may also be defined, e.g., defective pixel types corresponding to a pixel including more than one defective sub-pixels.

According to exemplary embodiments of the invention, a set of j color conversions corresponding to the defective pixel types may be determined for converting input pixel data into l_j-primary pixel data, wherein l_j denotes a predetermined number of primaries, e.g., corresponding to non-defective sub-pixels of the defective pixel type. For example, a color conversion for converting RGB pixel data into RGCBY pixel data may correspond to the sixth defective pixel type, and a color conversion for converting RGB pixel data into RGCB pixel data may correspond to a pixel including defective M and Y sub-pixels.

Embodiments of methods and systems for conversion of image data in three-primary formats into a more-than-three primary format, in accordance with exemplary embodiments of the invention, are described in International Application PCT/IL02/00410, filed May 23, 2002, entitled "DEVICE, SYSTEM AND METHOD OF DATA CONVERSION FOR WIDE GAMUT DISPLAYS" and published 12 December 2002 as PCT Publication WO02/099557 ("Reference 2"), the disclosure of which is

incorporated herein by reference. According to other embodiments of the invention, any other suitable conversion algorithm, e.g., a conversion algorithm using a $3xl_j$ color conversion matrix, may be implemented for converting image data in three-primary formats into a l_j-primary format.

Each defective pixel type may be related to a l_j-primary color conversion based on optimization of display attributes, for example, luminance uniformity, smoothness, or any other objective, subjective or relative display attribute.

According to some exemplary embodiments of the invention the number j of color conversions may equal the number i of defective pixel types, i.e. each of the color conversions may be related to one defective pixel type.

According to other exemplary embodiments j may be smaller than i. According to these embodiments, one color conversion may be related to two or more defective pixel types. For example, in a six primary (RGCBMY) color display, a CG defective pixel type including cyan and green defective sub-pixels, a C defective pixel type including a cyan defective sub-pixel, and a BC defective pixel type including blue and cyan defective sub-pixels, may all be related to one five-primary (RGBMY) color conversion.

Thus, according to exemplary embodiments of the invention, input pixel data intended to be reproduced by a defective pixel may be converted into converted pixel data, e.g., as described in Reference 2, using a color conversion method suitable for the type of defect of the defective pixel.

In some embodiments of the invention, the correction of a defective pixel may include subtracting the chromaticity value of one or more constantly "open" defective sub-pixels from the intended chromaticity value of the defective pixel. Based on the result of this subtraction, the system and/or method of the invention may adjust the values of the one or more non-defective sub-pixels of the defective pixel and/or the values of one or more sub-pixels of neighboring pixels.

Reference is made to Fig. 3, which schematically illustrates a flow chart of a method of correcting defective pixels according to exemplary embodiments of the invention.

According to exemplary embodiments of the invention, the method may include receiving three-primary input pixel data, as indicted at block 1302.

As indicated at block 1304, the method may include determining e.g., based on pre-obtained defective pixel information whether the input pixel data is intended to be reproduced by a defective pixel of the display device. The method may also include determining the type of the defective pixel, e.g., based on the defective pixel information.

As indicated in block 1306, if the input pixel data is intended to be reproduced using a defective pixel, then an l_j-primary color conversion, e.g., analogous to the conversion described in Reference 2, may be performed to convert the input pixel data into corresponding l_j-primary pixel data. The l_j-primary color conversion may be related to the defective pixel type, as described above. For example, if the display includes six primary colors, e.g., C, B, M, R, Y and G, and if the defective pixel includes a defective Y sub-pixel and a defective M sub-pixel, then a 4-primary (GCBR) color conversion may be performed.

As indicated by block 1308, if the pixel data is intended to be reproduced using a benign, i.e., non-defective pixel, then an n-primary color conversion, e.g., analogous to the conversion described by Reference 2, may be performed to convert the three primary pixel data into n-primary pixel data.

According to exemplary embodiments of the invention, controller 218 (Fig. 2) may be adapted to implement the method described above.

Reference is made to Fig. 4, which schematically illustrates a system 400 for defect pixel correction according to exemplary embodiments of the invention.

According to exemplary embodiments of the invention, system 400 may include an n-primary conversion module 404, e.g., analogous to the converter described by Reference 2, for converting three primary pixel input data 406 into n-primary pixel data 408.

According to exemplary embodiments of the invention, system 400 may also include a conversion selector 420. Conversion selector 420 may be able to determine, e.g., based on one or more timing and/or control signals 422, e.g., including video clock, Data Enable (DE), Horizontal synchronize (Hsync), and/or Vertical synchronize (Vsync) signals related to input pixel data 406, a pixel of the display intended to reproduce the input pixel data. For example, selector 420 may determine the position of the pixel intended to reproduce the input pixel data, e.g., based on one or more of signals 422.

Selector 420 may also be able to determine whether the pixel intended to reproduce the input pixel data is a defective pixel or a "benign" pixel. For example, selector 420 may compare the determined position of the pixel with pre-obtained defective pixel information, which may be stored in a memory 418 of selector 420. The defective pixel information may also include, for example, the type of the defective pixel. The defective pixel information may further include parameters, e.g., a color conversion matrix, of an l_j-primary conversion related to the defective pixel. Alternatively, selector 420 may be able to select the parameters of the l_j-primary conversion, e.g., based on the defective pixel type.

According to exemplary embodiments of the invention, if the pixel intended to reproduce the input pixel data is a defective pixel, then selector may select an l_j-primary color conversion related to the type of the defective pixel, as described above. Selector 420 may provide the parameters of the selected l_j-primary conversion to a color conversion module 416 able to convert pixel data 406 into corresponding l_j-primary data 414. For example, module 416 may include a conversion module analogous to the converter described in Reference 2 for converting three-primary data into at least three primary data.

According to exemplary embodiments of the invention, system may also include a multiplexer 410 to receive n-primary pixel data 408 and l_j-primary pixel data 414 and to provide an output 412 including either pixel data 408 or pixel data 414, e.g., based on a control signal 430 received from selector 420.

Thus, according to exemplary embodiments of the invention, if the input pixel data is intended to be reproduced by a defective pixel, then selector 420 may control multiplexer 410, e.g., using signal 430, to provide output 412 including l_j-primary pixel data 414. If the input pixel data is intended to be reproduced by a benign pixel, selector 420 may control multiplexer 410, e.g., using signal 430, to provide output 412 including n-primary pixel data 408.

While certain features of the invention have been illustrated and described herein, many modifications, substitutions, changes, and equivalents will now occur to those of ordinary skill in the art. It is, therefore, to be understood that the appended claims are

intended to cover all such modifications and changes as fall within the true spirit of the invention.

CLAIMS

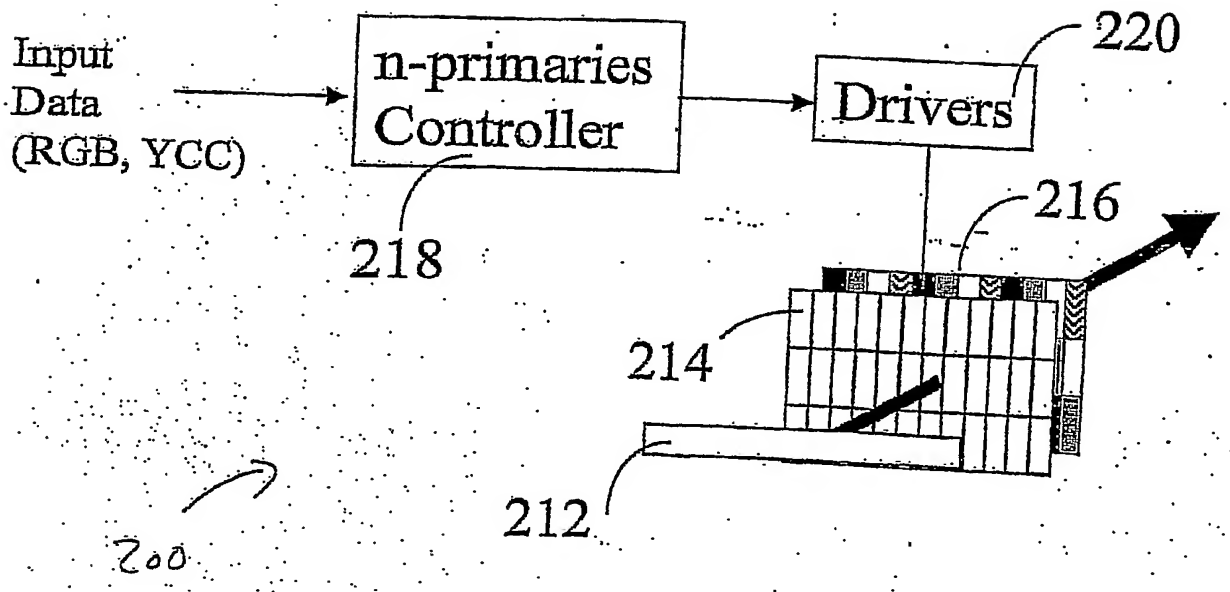
1. A system substantially as shown and described hereinabove.

2. A system substantially as illustrated in any of the drawings.

3. A method substantially as shown and described hereinabove.

4. A method substantially as illustrated in any of the drawings.

Fig. 1



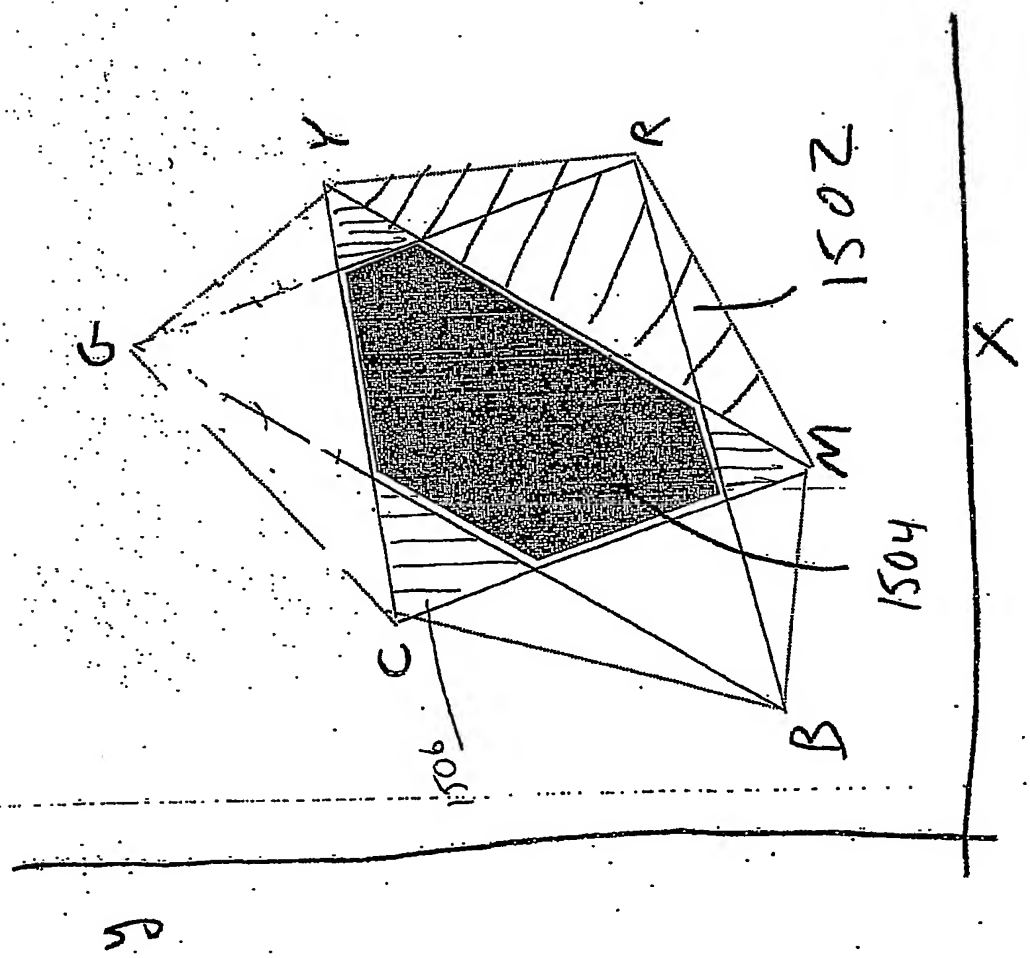


Fig. 2

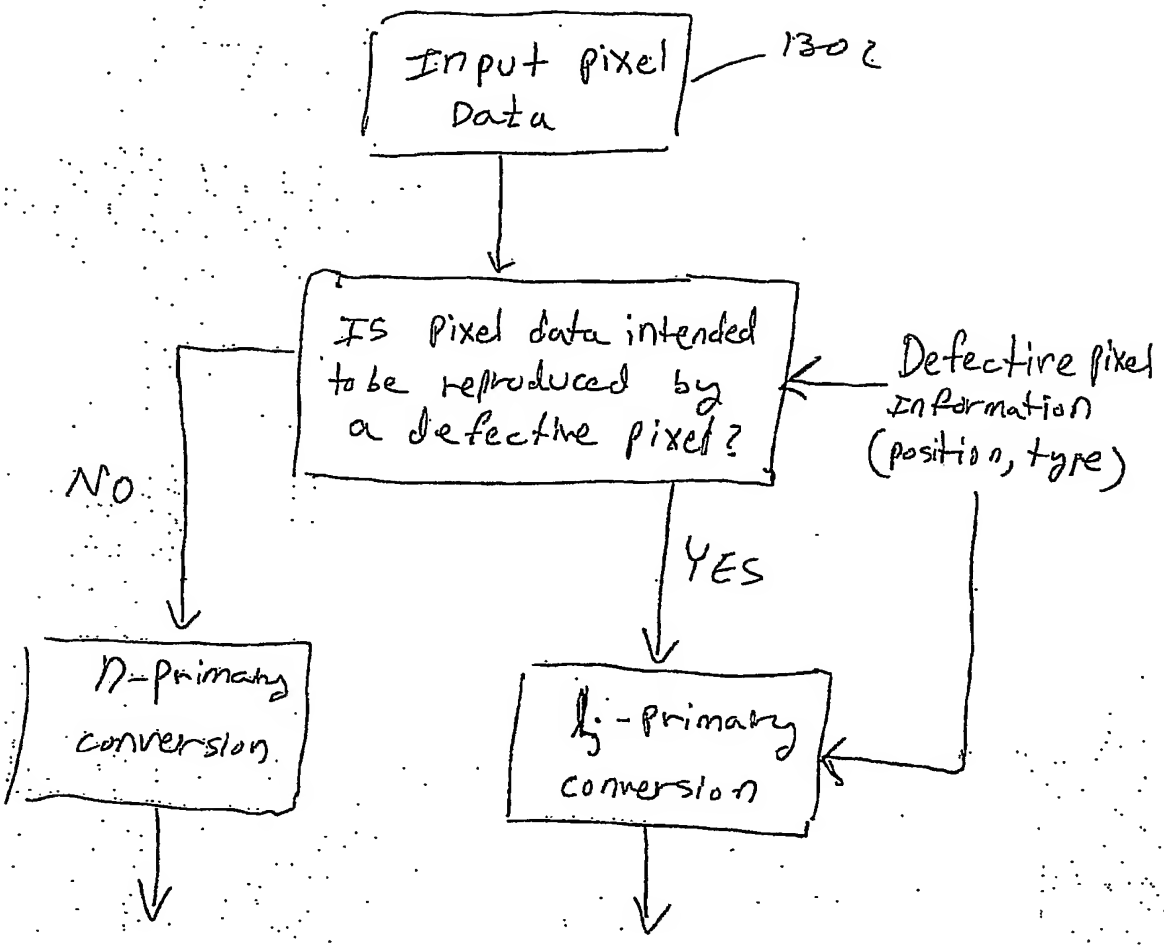


Fig. 3

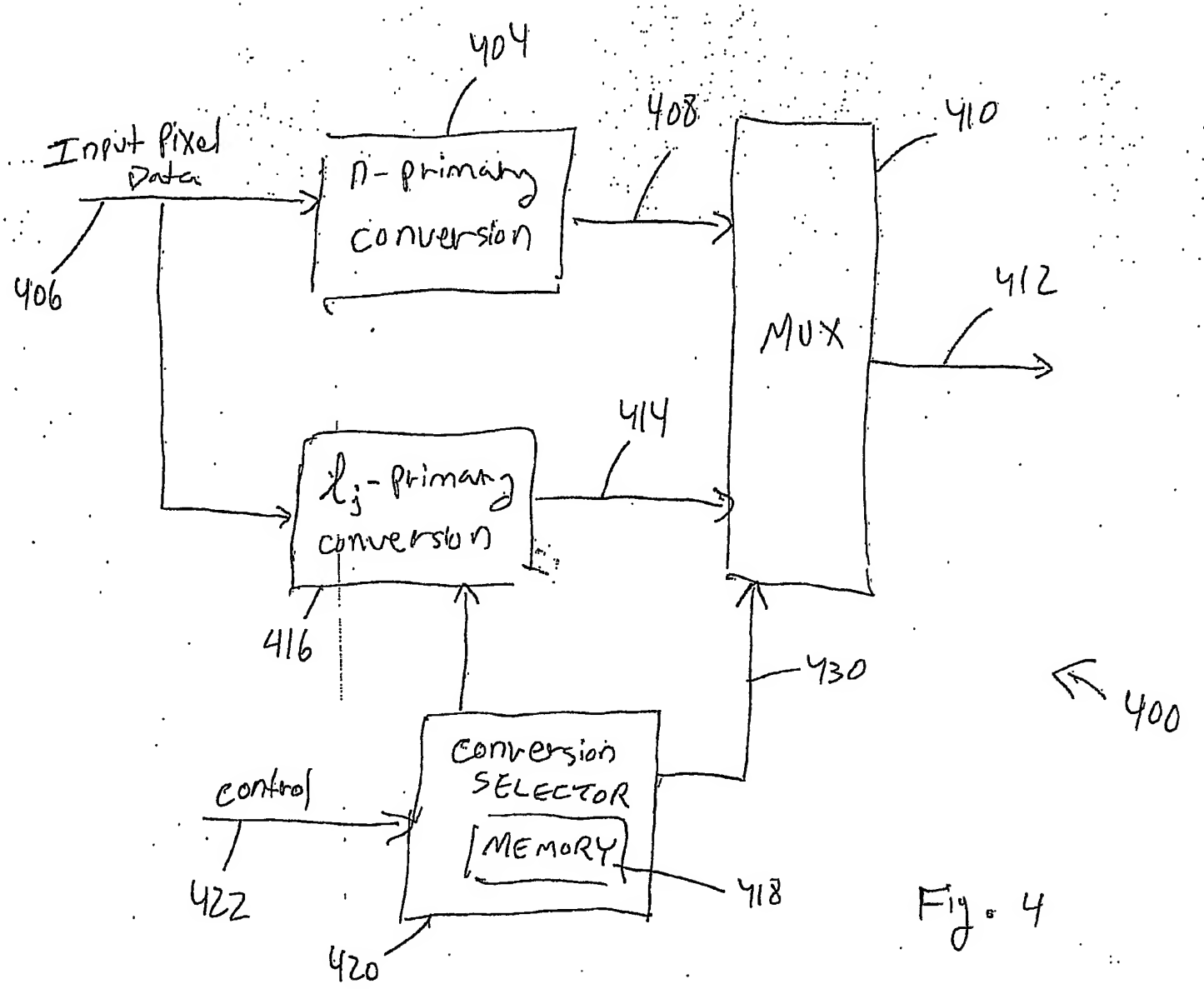


Fig. 4